THE EFFECT OF SUSPENDED CEILINGS ON THERMAL MASS TO REDUCE OVERHEATING

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ABSTRACT

Thermal mass has the benefit of regulating energy in buildings and generates potential savings in energy and CO_2 emissions. The effect of climate change with increasing air temperature intensifies even more the opportunities for the use of thermal mass to reduce overheating in summer and minimize the use of cooling energy, providing savings in energy and CO2 emissions. In most educational buildings, the thermal mass is hidden behind a compressed mineral wool suspended ceiling. The suspended ceiling produces a blocking effect for the use of the thermal mass to regulate the indoor conditions, avoiding the loading and unloading of the thermal mass as a regulatory mechanism for indoor temperature.

The aim of this study was to investigate the impact of suspended ceilings on overheating and the benefits of using thermal mass to reduce overheating.

The approach used in this study was based on dynamic thermal modeling to analyse the overheating performance of a test room with suspended ceiling and with the thermal mass exposed. The testing room was simulated under weather conditions for two locations in Europe, London in the United Kingdom and Munich in Germany.

The test room was modeled and simulated using energyplus in DesignBuilder. The test room was modeled using medium weight construction in accordance with the UK Building Regulations Part L2 2010. All room surfaces were adiabatic apart from the south facing wall, which compromised 50% of glazing. The test room was naturally ventilated and a night cooling ventilation strategy was used to cool down the thermal mass. No cooling was used in the simulations to be able to quantify the benefits provided by the thermal mass to reduce overheating.

An overheating limit of 28 ºC was chosen in accordance with the Building Bulletin 101 Ventilation of School Buildings to assess the performance of the thermal mass during the simulations.

The simulation results show that by exposing and making use of the room thermal mass, the number of hours above 28 ºC can be reduce by at least 33% in Munich and 49% in London. The reduction in overheating hours will consequently minimise the need for cooling energy in summer providing savings in energy and CO2 emissions.

Keywords: thermal mass, suspended ceiling, overheating

INTRODUCTION

Thermal mass has the benefit of regulating energy in buildings and generates potential savings in energy and CO_2 emissions. Previous studies (Marceau et al, 2007) have highlighted the energy cost savings, which could be achievable by optimizing thermal mass in the structural frame of buildings. The effect of climate change with increasing air temperature intensifies even more the opportunities for the use of thermal mass to reduce overheating in summer and minimize the use of cooling energy, providing savings in energy and CO2 emissions. The Energy Saving Trust (2005) and the Building Research Establishment (BRE) (2005) had presented the benefits of coupling thermal mass and ventilation in housing to avoid overheating. According to the Zero Carbon Hub (2012), thermal mass and purge ventilation have a beneficial effect on reducing overheating. This study focus on educational buildings, there mostly the thermal mass is hidden behind a compressed mineral wool suspended ceiling for acoustic reasons, which are outside of the scope of this study. This suspended ceiling produces a blocking effect for the use of the thermal mass to regulate the indoor conditions, avoiding the loading and unloading process of the thermal mass to be used as a regulatory mechanism for comfort indoor temperature.

Overheating is a term used here to describe the undesirable effect of higher than comfortable temperatures, which exceed the target room temperatures. Overheating increases in constructions with no thermal mass or when the thermal mass is insulated from ambient-room temperatures, such as with the used of suspended ceilings. An overheating limit of 28 ºC was chosen in accordance with the Building Bulletin 101 Ventilation of School Buildings (2006) to assess the performance of the thermal mass during the simulations.

The aim of this study was to investigate the impact of suspended ceilings on overheating and the benefits of using thermal mass to reduce overheating.

METHOD

The test room was modeled and dynamically simulated using energyplus in DesignBuilder. The test room was modeled with dimensions 7.5m x 7.5m x 3.5m, as shown in Figure 1, and U-values for internal floors with and without suspended ceilings as presented in Figure 2. The test room was naturally ventilated and a night cooling ventilation strategy was used to cool down the thermal mass. No cooling was used in the simulations to be able to quantify the benefits provided by the thermal mass to reduce overheating.

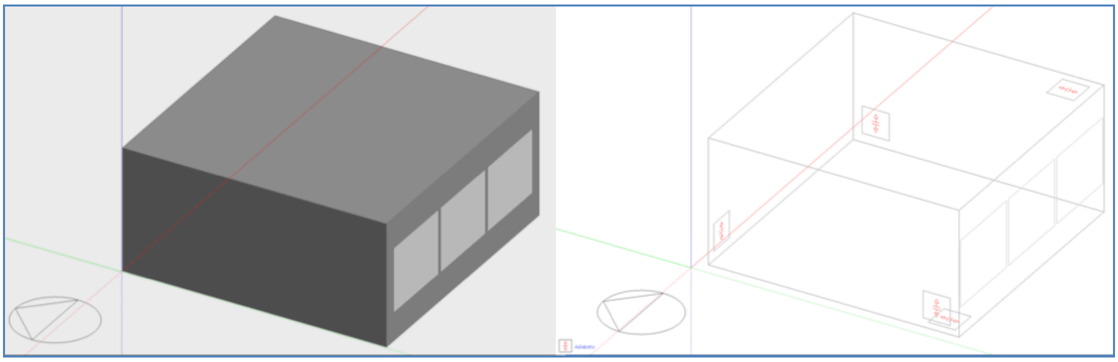


Figure 1: Exemplar room for simulation.

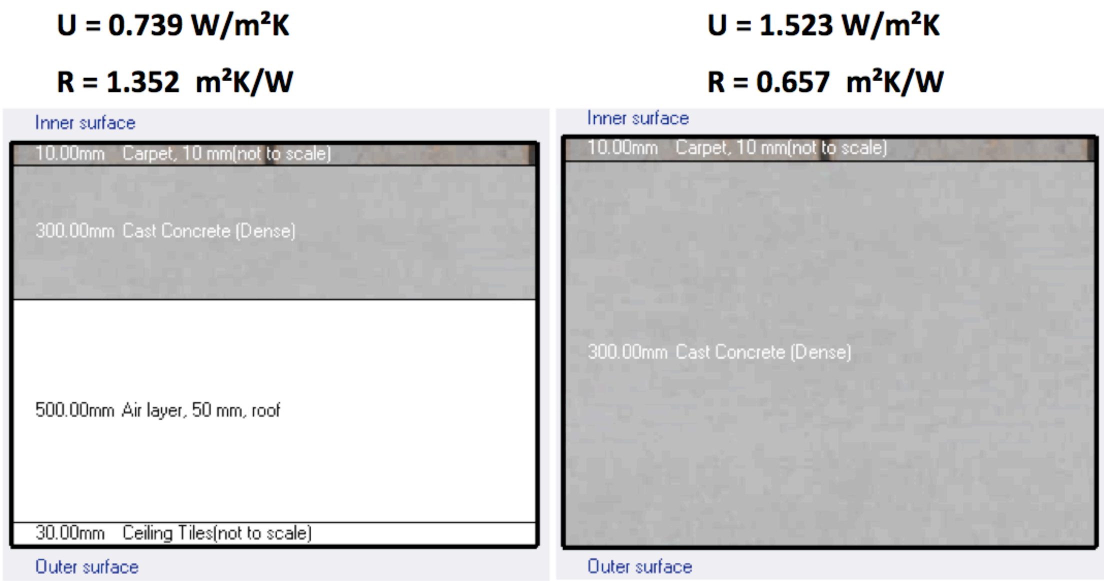


Figure 2: U-values for internal flooring with (left) and without (right) suspended ceiling.

The dynamic computational simulation in DesignBuilder had the following parameters:

- Simulated locations in London (United Kingdom) and Munich (Germany).
- Medium weight construction according to Part L2 2010 (UK).
- All surfaces adiabatic apart from south wall being external.
- 50% glazing in south wall.
- Office equipment load of 10 W/m^2.
- Lighting load of 0 W/m^2.
- People density of 0.111 people/m^2 (well above typical primary teaching spaces according to BB103 Area Guidelines for Mainstream Schools (2014)), following an occupancy schedule from 9:00 to 17:00
- Constant infiltration of 0.5 air changes per hour (acph).
- Natural ventilation rate of 1.5 acph, following a schedule from 8:00 to 19:00
- Night ventilation rate of 6 acph, following a schedule from 24:00 to 6:00
- One year simulation.

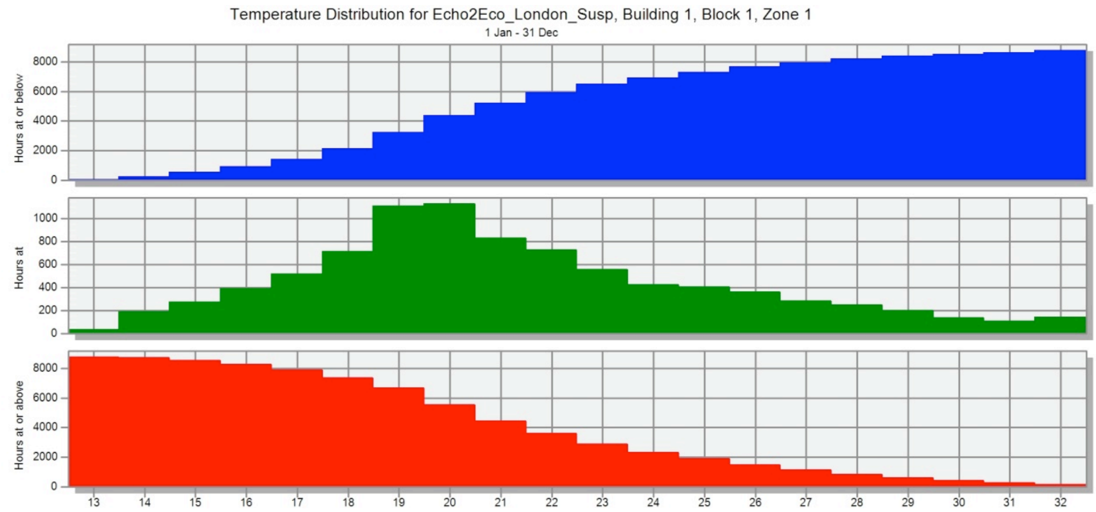
Ventilation rates achieved through single side tilted windows following parameters as described in the Building Bulletin 101 Ventilation of School Buildings (2006) for the ClassCool tool.

RESULTS

In terms of assessing the overheating performance (defined in 4.1) with and without the suspended ceiling, four simulations were solved using the dynamic Energyplus engine in DesignBuilder without the use of (simulated) cooling preventing overheating. Two simulations were provided for London location (with and without suspended ceiling) and two simulations for Munich location (with and without suspended ceiling).

Figure 3 shows the temperature distribution results for London with the use of suspended ceiling as an example. Similar results were collected and analysed for the other computational simulations, the final results for overheating hours above 28 ºC are summarised in Figure 4.

Figure 3: Temperature distribution results for London with false ceiling.



	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Hours at or below	33.5	224.0	497.0	884.5	1400.5	2113.5	3224.0	4353.5	5181.0	5907.0	6463.5	6884.5	7288.5	7648.5	7931.5	8179.0	8375.0	8511.5	8619.0	8760.0
Hours at	33.5	190.5	273.0	387.5	516.0	713.0	1110.5	1129.5	827.5	726.0	556.5	421.0	404.0	360.0	283.0	247.5	196.0	136.5	107.5	141.0
Hours at or above	8760.0	8726.5	8536.0	8263.0	7875.5	7359.5	6646.5	5536.0	4406.5	3579.0	2853.0	2296.5	1875.5	1471.5	1111.5	828.5	581.0	385.0	248.5	141.0

Temperature bins (°C)

Exposing the thermal mass by elimination of the suspended ceiling reduces the overheating hours above 28^0 C by 33% in Munich and 49% in London compared to the same room featuring a suspended ceiling with accompanying isolation of the thermal mass from ambient temperatures.

The number of overheating hours correlates with the need for cooling in a building and subsequently with the energy use and carbon emissions that cooling would incur. The higher the number of overheating hours, the more energy and carbon emission will be driven by cooling to alleviate the overheating.

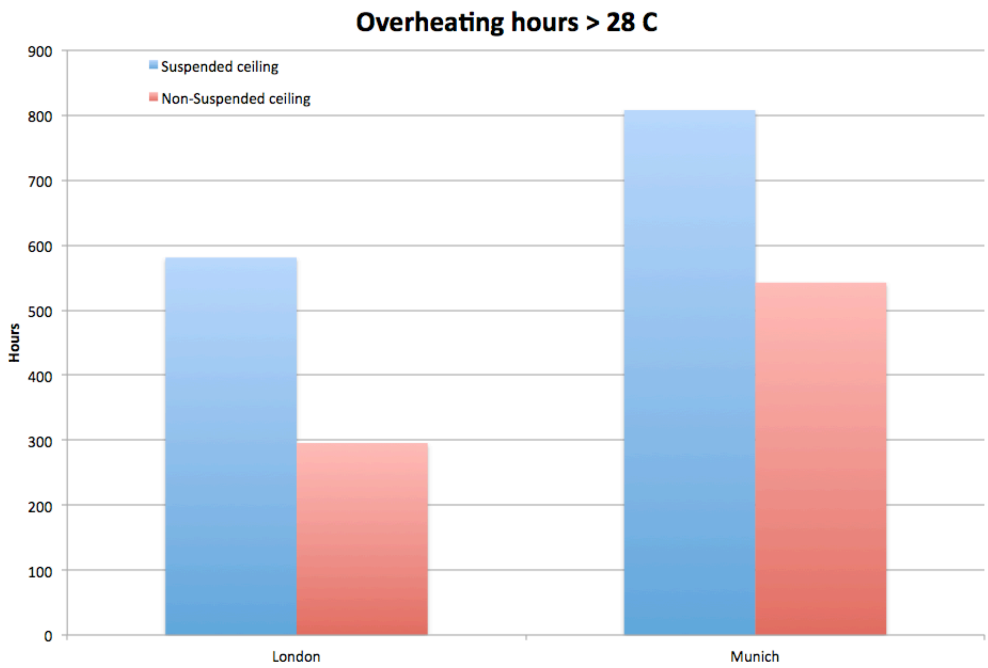


Figure 4: Overheating hours above 28⁰C for London and Munich, with and without false ceiling.

DISCUSSION

Exposing the thermal mass by elimination of the suspended ceiling reduces the overheating hours above 28^0 C by 33% in Munich and 49% in London compared to the same room featuring a (simulated) suspended ceiling with accompanying (simulated) isolation of the thermal mass from ambient temperatures.

The number of overheating hours correlates with the need for cooling in a building and subsequently with the energy use and carbon emissions that cooling would incur. The higher the number of overheating hours, the more energy and carbon emission will be driven by cooling.

The simulation results show that by exposing and making use of the room thermal mass, the number of hours above 28 ºC can be reduce by at least 33% in Munich and 49% in London. The reduction in overheating hours will consequently minimise the need for cooling energy in summer providing savings in energy and CO_2 emissions.

This study agrees with the advise in terms of avoiding overheating from Energy Saving Trust (2005), the Building Research Establishment (BRE) (2005) and Zero Carbon Hub (2012). Furthermore, this study shows that the use of a suspended ceiling can have an unwanted insulating effect on the surface temperature of the overlying thermal mass, impeding energy transfer, and hence reducing the efficacy of the thermal mass's ability to moderate ambient temperatures and consequently lead to overheating.

CONCLUSION

This study shows that the use of a suspended ceiling can have an unwanted insulating effect on the surface temperature of the overlying thermal mass, impeding energy transfer, and hence reducing the efficacy of the thermal mass's ability to moderate ambient temperatures and consequently lead to overheating.

This study shows that the elimination of thermally insulating suspended ceilings could potentially saves energy by exposing the thermal mass of overlying structures, moderating undesirable thermal overheating, and therefore reducing or eliminating the need for artificial cooling.

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